MASTER OF SCIENCE
IN
PHYSICS

QUANTUM COMPUTATION

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Two seemingly unrelated scientific disciplines, information processing and quantum mechanics, were separately developed, until physicist Richard Feynman proposed their combination. Today, quantum computation is at the forefront of research in theoretical physics and computer science. The objectives of this thesis are to present an introduction to the subject of quantum computation and its potential, and to analyze the physics underlying the operation of one of the proposed realizations of a quantum logic gate, based on cavity quantum electrodynamics (QED). The fundamental aspects of quantum mechanics are discussed that may be a revolutionary new way to process information. The appropriate theoretical background is presented of QED needed to understand the proposed realization of a quantum gate. The advantages and disadvantages are identified of this realization. The phenomenon of decoherence are addressed and discussed, the most fundamental obstacle to overcome for the development of practical quantum computers. Finally, some of the possible military applications are presented, along with thoughts for the future of this field. It is concluded that quantum gates based on cavity QED are feasible with current technology. However, the construction of a quantum network with these gates is not feasible, mainly due to the decoherence problems.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Quantum Computing, Cavity QED

NUMERICAL CALCULATION OF THE WANNIER FUNCTIONS OF GaAs/$Al_{0.25}Ga_{0.75}As$ SUPERLATTICE STRUCTURE

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This thesis presents the numerical calculation of the Wannier functions (an(z)) of the GaAs/$Al_{0.25}Ga_{0.75}As$ superlattice structure. The Wannier functions are linear combinations of the Bloch functions GaAs/$Al_{0.25}Ga_{0.75}As$ that can be viewed as a convenient mathematical instrument to get around the lack of orthogonality of the tight binding formulation and are useful tool when the position of an electron has physical importance. However, except for finding a variational principle for the energy levels of one dimensional crystals in terms of the Wannier functions and simple cubic lattice calculations for instructional reasons, models have not been calculated or plotted showing the theory can be expanded to more complex superlattice structures. An algorithm was developed to calculate numerically and plot the Wannier functions of the GaAs/$Al_{0.25}Ga_{0.75}As$ superlattice structure and hence prove that these functions can be calculated even for complex structures. By using the plots of numerical modeling, the peculiar properties of the Wannier functions were displayed:

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a. Wannier functions are real;
b. they fall off exponentially; and
c. they are either symmetric or anti-symmetric about $z=0$.

DoD KEY TECHNOLOGY AREAS: Sensors, Electronics, Modeling and Simulation, Materials, Processes, and Structures

KEYWORDS: Wannier Functions, Superlattice Structure, Bloch Functions